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ABSTRACT *(MAXIMUM 200 WORDS)* Current and planned space and terrestrial network assets cannot sufficiently provide the robust network required to support mobile Marine Corps ground forces. Additionally adversaries continue to gain technological parity in disrupting or nullifying space and terrestrial networks. Therefore an alternative such as aerial networks must be explored specifically as a supportable concept or operations for the Marine Corps, which will ultimately mitigate current capability gaps for highly mobile ground forces throughout the Marine Corps.			
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MASTER OF MILITARY STUDIES

TITLE:
Extending the Ground Force Network: Aerial Layer Networking

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Executive Summary

Title: Extending the Ground Force Network: Aerial Layer Networking

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Thesis: To close the digital divide gap holistically and posture the Marine Corps as the crisis response force for the 21st century, a paradigm shift in thinking is required. This shift requires a focus on how best to support network-enabled warfare despite conditions of dispersion, distance, threat, complex terrain, movement, and adverse weather. Therefore to better expand the ground force network as required, aerial relay networking concepts and capabilities must be expanded and explored throughout the Marine Corps.

Discussion: Today ground forces find themselves engaged in asymmetrical operations. These operations require novel and unique approaches to enabling communications across highly dispersed forces. Ground forces require the network to provide improved connectivity for the sharing of mission command, communications, and intelligence data. The network must also enable information sharing while the ground force maintains mobility and lethality. The aerial tier network will extend and expand the network to provide increased connectivity to ground forces.

Current and planned space and terrestrial network assets do not sufficiently provide the robust network required of tactical edge forces. The aerial tier is currently the most underutilized layer of communications transport. At the same time, the aerial tier offers the greatest potential for network expansion.

The Marine Corps being tactical in nature must begin to focus on the disadvantage user or those units and leaders executing complex actions at distances far removed from their higher headquarters. In doing so concepts such as Mission Command, Ship-to-Objective Maneuver (STOM), and Enhanced MAGTF Operations (EMO) can be achievable. The goal should simply be to give tactical commanders a capability to extend and expand their existing networks. This can be accomplished by formulating a concept for aerial networking throughout a broad range of operations and ensuring synchronization with other joint services as aerial networking technologies emerge and mature.

Conclusion: To remain flexible and agile in anticipated complex environments of the future, the Marine Corps must remain innovative in the development of new concepts and technologies. Most importantly, a focus on expanding C2 and situational awareness to small unit leaders to support decentralized decision-making is paramount. To accomplish this, the Marine Corps must make a concerted effort to advance aerial tier concepts and technologies. This effort will ultimately require a coherent path ahead for the Marine Corps, which consist of: inclusion of an aerial tier capability into the existing NOTM program, inclusion of aerial tier concepts into Marine Corps current and future concepts, and the leveraging and experimentation of existing aerial layer networking DoD technologies.

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Preface

The central purpose of my research is twofold: To identify the importance of increasing command and control (C2) network capabilities to highly mobile tactical units throughout the Marine Corps and the steps required for the Marine Corps to make this reality. The insatiable appetite for near real-time information on the battlefield will not subside, but only increase exponentially as asymmetrical threats and increased complex environments, push highly mobile Marine Corps elements to the edge of the proverbial operational envelope. This will not only strain tactical network enclaves but may also render them useless. Therefore, I believe an incessant reliance on terrestrial and satellite communications mediums to mitigate these challenges is unrealistic. I have operated numerous times where the terrain and environment negated the use of terrestrial LOS communications and subsequently shifted to a sole reliance on SATCOM. I have also been in scenarios where operational necessity discontinued my priority and subsequent use of SATCOM, thus leaving me with very little options for communications. This is the reality and such the Marine Corps, in my opinion must develop an aerial relay network capability for the future. This I believe would better augment existing terrestrial and satellite capabilities and significantly close the communications gap that currently exists for tactical edge elements. I do not claim to resolve this issue here, but hope to begin a dialogue to the importance and need for this capability currently and into the future. I ultimately see this study as one small step in that direction.

Introduction

The introduction of communication network capabilities on the battlefield, has dramatically altered the means by which today's military communicates. Continual advancements in technology have enabled military forces, the ability to ascertain strategic, operational, and time sensitive information that was rarely achievable a decade ago. These improvements in communication technologies were the lynchpin to early successes garnered by the Marine Corps during combat operations in support of Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). Most notably, the realization of enhanced command and control (C2) capabilities, enabling synchronization efforts throughout the joint area of operations (JOA). This was apparent during the initial invasion efforts in both Afghanistan and Iraq. Joint forces expertly weaved conventional force capabilities (warfighting functions) with precision-guided munitions through critical linkages, acquired via an intelligence apparatus, which leveraged robust enterprise communication links at the highest levels of command. However, these Department of Defense (DoD) robust enterprise communication architectures are presently designed to support large-scale fixed organizations and rely primarily on satellite mediums. Thus, they are inadequate in tactical environments, and are neither readily available nor affordable to multiple units operating simultaneously in tactical locations.

The intent of this document is to provide the reader a framework for the complexities the Marine Corps faces in the future, in regards to extending network services to mobile key leaders across all levels, with an emphasis on company and below elements. This will have to be accomplished in a less then perfect austere environment, where the reliance on infrastructure becomes a myopic fallacy. Thus, airborne network relay capabilities (integration of tactical radio networks with airborne platforms) become a necessity in achieving the goal of network extension. Additionally the reader must understand, that the use of aerial relays to expand command and control (C2) on the battlefield is not necessarily a new endeavor. It is however an ever-changing paradigm, due to an increase in asymmetrical characteristics on the battlefield and a current fiscally constrained environment. Expansion of this aerial layer or tier will also see increases due to an ever-growing enemy threat to space. These along with other limitations will revolutionize the way services view and implement the aerial tier in the future. This document will focus on current gaps in C2 at the tactical level, current initiatives in the DoD in regards to aerial layer network concepts and capabilities, and finally concentrate on a proposed path ahead for the Marine Corps in developing and implementing aerial layer network capabilities.

The Problem

Technological advancements in communications equipment and capabilities on today's battlespace have also created a disparity chasm, between forces afforded the opportunity to employ such technologies, and those forces employing less capable antiquated systems. More specifically those forces not bound to static forward operating bases. Furthermore, this disparity in overall communications capabilities is widening, as engagements shift from symmetrical operations to asymmetrical operations as witnessed today, and envisioned to endure during future conflicts. From this shift a proverbial digital divide has manifested through the requirement to determine density and the echelon level, critical C2 links will ultimately reside.[1] This is in fact has contributed to a skewed vision on how to close the digital divide in providing the right information to the right Marine at the right time, in order to make timely and informed decisions on an asymmetrical battlefield.

The Marine Corps will continue to operate in an environment that is increasingly complex, uncertain, and dynamic.[2] Employment of asymmetric strategies by adversaries, the advancements of weapon systems, and technological parity will continue to create additional stresses on all elements of the force. To thwart these threats now and into the future, ground tactical forces will require increased network capabilities, delivering connectivity for the sharing of mission command, communications, and intelligence data. All the while these capabilities must enable the ground tactical force unhindered mobility and support to disaggregated operations. A solution fashioned at resolving these digital divide challenges, has primarily focused on increasing satellite communications capabilities and their overall availability. While extremely practical in overcoming distance, terrain, and obstacles to line-of-sight (LOS), satellite system resources are insufficient in their capacity to connect all required users on the battlefield, both today and into the future. Furthermore, the cost associated with satellite communications, prohibits proliferation as required by highly mobile ground forces.

To close the digital divide gap holistically and posture the Marine Corps as the crisis response force for the 21st century, a paradigm shift in thinking is required. This shift requires a focus on how to best to support network-enabled warfare despite conditions of dispersion, distance, threat, complex terrain, movement, and adverse weather. Therefore to better expand the ground force network as required, aerial relay networking concepts and capabilities must be expanded and explored throughout the Marine Corps. While not the proverbial silver bullet, these concepts ultimately will augment existing systems such as terrestrial and satellite tiers, by providing improved efficiency and enhanced support to the warfighting functions.

Background

Throughout history, military planners as well as commanders have always desired the means by which to command and control forces effectively on the battlefield. To accomplish this, terrain became paramount in achieving these desires. Advantaged communication nodes have historically played significant roles in combat operations.[3] Ground based retransmission sites were routinely established on a key terrain features such as hilltops. These positions provided adequate retransmission capabilities to overcome distances, blockages, and or obstacles to LOS communications. However as technologies advanced, namely data networking, the systems fashioned for retransmission sites did not keep pace with the development of other technologies. This in turn, left antiquated systems primarily delivering voice only capabilities to forces in disadvantaged locations. A shift has taken place in attempting to deliver data to the tactical edge or locations in which disadvantaged users operate.[i] Therefore current retransmission systems require networking capabilities to link forces in order to enable mutual supporting actions. This is gradually becoming a reality through the advent of network capable tactical radios, but connectivity to gateways for vital linkages to higher echelons of command is still inadequate.

Conversely in non-combat environments such as civilian applications, the methods to overcome blockages and obstacles in communications are tackled quite differently. To mitigate the dead-spot phenomena for communications, civilian and industry partners employ both satellite communications and networks of terrestrial relay towers. This enables an interlocking network, based on a robust infrastructure support apparatus.

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[i] Aaron Griggs, *Characterization Framework and Design Patterns For the Disadvantaged User*, The MITRE Corporation, 2007. 1. Many Service Oriented Architecture (SOA) approaches in use today presume the consistent availability of reliable networks and limitless resources. This is often not the case for a DoD user operating at the tactical edge who may be disadvantaged in terms of network and resource availability.

Thus, the interlocking network functions via an integrated workforce, dedicated to maintaining and improving overall network functionality. Furthermore it is dependent on static towers, repeaters, and support structures. Also reliant power sources generate continuous uninterrupted and redundant power supply to vital communications nodes throughout the network. Lastly, and most importantly, is the overall redundancy provided throughout these networks. Redundancy is provided by protected underground cabling systems such as fiber optics and copper wiring integrated into the interlocking network of towers and support structures.

While this is an ideal situation for network connectivity, the military operates in austere environments and many times in environments that are woefully lacking infrastructure of any kind. As with retransmission sites, interlocking network towers throughout the battlespace will require persistent security as to thwart enemy counteractions to any expeditionary established structures. This sobering reality will negate this practice of establishing robust retransmission capabilities, since the forces to secure such actions will not be available in the quantities required. Therefore unique approaches will need to be identified in order to provide a surrogate capability to this interlocking networking notion, and thus reduce the digital divide. Thus, reality becomes apparent as the Marine Corps attempts to categorize the future security environment as becoming increasingly complex, uncertain, chaotic, and distributed. These future security characteristic traits that exclude civilian applications, for networking requirements, are also readily found in operating concepts produced and touted by the Pentagon.

The published *Marine Corps Operating Concepts*, describes the fundamental characteristics of war as being inherently uncertain, requiring distributed decision makers to the point of action in order to discern the situation, gain better awareness and act.[4] Additionally decision makers close to the tactical edge will be able to more rapidly develop or exploit opportunity and if given appropriate authority, can take timely and effective action.[5] This ability of forces to gather, process, and disseminate battlespace information more rapidly will garner tremendous advantage in operations and will be predicated by the continual advancements in networking technologies. Furthermore combat operations over the past decade have underscored two significant points. First, adversaries will continue to adapt, and second the Marine Corps must continually assess and adapt its warfighting capabilities in order to ensure mission success. In doing so the Marine Corps must look into ways to enhance Marine Ground Task Force (MAGTF) capabilities to best support the requirements of the future security environment.[6]

In support of these ideals, the Marine Corps has constructed the *MAGTF C2 roadmap*. In doing so, the Marine Corps is attempting to provide networked C2 capabilities connecting all elements of the MAGTF with joint forces and coalition partners to create unparalleled information sharing and collaboration through the synchronization and integration of force elements at the lowest levels.[7] At its core, *MAGTF C2 roadmap* focuses on the following ideals: commander/leader centric, network-enabled expeditionary forces, information assurance, shared situational awareness, and C2 functions performed by all echelons anywhere in the operational environment.[8] While adaptive in its approach, the *MAGTF C2 roadmap* does not place emphasis on the employment of aerial assets, to either augment planned systems or function exclusively in providing the network expansion capabilities to the lowest elements in the MAGTF. This is a mistake, since the aerial teir[ii] is currently the most underutilized layer of communications transport.

[ii] Joint Requirements Oversight Memorandum (JROCM), *Endorsing the Joint Aerial Layer Network Initial Capabilities Document*, 27 October 2009. JROC endorses a diverse, three tiered network (space, air, and surface); to rely on any single tier creates a strategic vulnerability and is cost prohibitive. Mobile leaders at all echelons require robust, multi-tier (space, aerial, and surface), high capacity communications networks at all security levels to employ military capability across the range of military operations. The aerial tier is currently the most underutilized layer of communications transport.

At the same time, it offers the greatest potential for network expansion. Furthermore the aerial tier or aerial layer ensures more robust and agile network extension to the tactical edge overcoming austere, challenging, and degraded communication environments.

Employment of Airborne Relays

Airborne relays track their lineage to employment during the Vietnam conflict. The limitations of radio systems during this period encouraged military planners to find unique methods, in providing increased radio coverage throughout triple canopy jungles in Southeast Asia. In doing so, helicopters were equipped with multiple FM radios, in order to provide airborne retransmission capabilities for voice nets exclusively. While somewhat successful, resources in regards to cost and overall asset availability negated long-term adoption and employment of this capability.[9] What did endure however was a continued willingness of military practitioners to explore novel ways in extending C2 throughout the battlefield, via aerial techniques.

Some of these techniques have included airships, balloons, convectional aircraft, and unmanned aircraft equipped with communication payloads. Most notably the Aerostat balloon was used in Iraq and Afghanistan in order to extend radio coverage for base operations and convoy support roles. Additionally the balloon provided radar functions for force protection missions and is currently serving on the U.S. Mexico border to intercept drug and human trafficking rings. Figure 1 depicts an aerostat balloon prior to deployment in Afghanistan.

Figure 1. Employment of Aerostat Balloon

The Marine Corps has also employed the Combat SkySat balloon in order to reduce its reliance on SATCOM. The balloon acts as a surrogate geosynchronous satellite by retransmitting voice and data circuits and extending the range of UHF communications. The system is designed to extend communications ranges up to a 600-mile radius and has been employed since fielding in real world operations since 2008 with much success.[10] Their primary use so far has been C2 extension for aircraft operating outside the communications envelope during amphibious operations. Figure 2 depicts Marines with the 15th Marine Expeditionary Unit (MEU) training with the Combat SkySat balloon system.

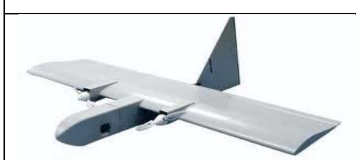
Figure 2. Combat SkySat training for the 15th MEU

Unmanned Aircraft Systems

Unmanned Aircraft Systems (UAS) has been a primarily enabler for military forces and has seen tremendous growth in the United States military since 2001.[11] UAS's conduct persistent surveillance for situational awareness and have been traditionally associated with intelligence collection efforts, most notably in support of Overseas Contingency Operations. However, UAS roles have expanded to include precision targeting platforms, relay extension platforms for communications, and logistical resupply platforms for austere location support. Unmanned systems continue to enable Marines at the lowest tactical level to see beyond the next hill or obstacle, but rarely provided both eyes and ears simultaneously.

The DoD is focused on exploiting this capability further and in doing so, is focused on enabling robust networks, to fully support information and knowledge connectivity with required capacity.[12] Furthermore, increasing network extension capabilities will provide the necessary C2 at the tactical edge while operations are conducted in degraded or interrupted network environments.[13] Due to limited availability and capacity of the space segment, long range and beyond-line-of-site (BLOS) connectivity gaps for ground forces exists today. The Air Force Vision for Aerial Layer Networking in 2024 elaborates this point, by focusing on extending and augmenting space and surface networks to connect, reconnect, and enable collaboration of warfighters executing specific missions and tasks.[14] Therefore these network extension goals are paramount in closing the digital divide gap at the tactical level.

The Marine Corps must stay fully engaged with the increased developments in unmanned systems in order to achieve its vision for concepts such as Ship-to-Objective Maneuver (STOM), Enhanced MAGTF Operations (EMO), Mission Command, and Distributed Operations (DO). Currently the Marine Corps maintains and operates UAS platforms in tiers, which correspond to the level of command the platform supports. These groups or tiers are broken into three levels; tier 1 is flown at the battalion and below, tier 2 is flown at Division and below, and tier 3 flown at the Marine Expeditionary Force and below. These and future systems will be vital in leveraging the aerial tier for overall network expansion to the tactical edge. Table 1 depicts a list of the current Marine Corps UAS inventory broken down by tier. With acknowledgement of the importance of distributed networks throughout the battlefield, what do Marine Forces ultimately require in the future, and which current C2 gaps require mitigation?

WASP	**System Characteristics**	**Description**	**Performance**
	***Weight:*** 0.7lb ***Length:*** 11in ***Wingspan:*** 16in ***Payload Capacity:*** 25lb ***Engine Type:*** Electric Battery ***Tier: I***	Rugged unmanned air platform designed for front-line reconnaissance and surveillance over land or sea. Serves at the company level and below by virtue of its small size and quiet propulsion system	***Ceiling (MSL):*** 10,000ft ***Radius:*** 2-3nm ***Endurance:*** 60min ***Cruise Speed:*** 15-35kt ***Sensor:*** 2 color cameras
RQ-14 Dragon Eye	**System Characteristics**	**Description**	**Performance**
	***Weight:*** 4.5lb ***Length:*** 2.4ft ***Wingspan:*** 3.8ft ***Payload Capacity:*** 1lb ***Engine Type:*** Electric Battery ***Tier: I***	Company/platoon/squad level with an organic reconnaissance, surveillance, and target acquisition capability out to 2.5 miles.	***Ceiling (MSL):*** 10,000ft ***Radius:*** 2.5mi ***Endurance:*** 45-60min
Raven 11B	**System Characteristics**	**Description**	**Performance**
	***Weight:*** 4.2lb ***Length:*** 36in ***Wingspan:*** 55in ***Payload Capacity:*** 11.2oz ***Engine Type:*** Direct Drive Electric ***Tier: I***	Remotely controlled from its ground station or fly completely autonomous missions using global positioning system (GPS). Standard mission payloads include EO color video and IR camera capabilities.	***Ceiling (MSL):*** 15,000ft ***Radius:*** 10km (LOS) ***Endurance:*** 90min ***Cruise Speed:*** 26kt

RQ-7 Shadow 200	System Characteristics	Description	Performance
	***Weight:*** 375lb ***Length:*** 11.33ft ***Wingspan:*** 14ft ***Payload Capacity:*** 60lb ***Engine Type:*** MOGAS ***Tier: II***	Shadow is rail-launched via catapult system. Its gimbaled optical payload EO/IR sensor relays video in real time via a C-band LOS data link.	***Ceiling (MSL):*** +15,000ft ***Radius:*** 125km ***Endurance:*** 5-6hr ***Cruise Speed:*** 110kt
Scan Eagle	**System Characteristics**	**Description**	**Performance**
	***Weight:*** 37.9lb ***Length:*** 3.9ft ***Wingspan:*** 10.2ft ***Payload Capacity:*** 60lb ***Engine Type:*** Gasoline ***Tier: II***	Scan Eagle carries an internally stabilized camera turret for EO/IR imagery. Its sensor data links have integrated cursor on target capabilities, which facilitates integration with larger UAS like the Predator.	***Ceiling (MSL):*** 16,400ft ***Radius:*** 60km ***Endurance:*** 15hr ***Cruise Speed:*** 70kt

Table 1. USMC UAS Programs of Record, Department of Defense Unmanned Aircraft Systems Roadmap FY2005-2030

Marine Corps ground forces ultimately require a robust, high capacity communications network that is capable of providing responsive information transport to all users over extended distances, in complex, mountainous and urban terrain, and while on the move. To accomplish this, the network must transition from its current reliance on relatively fixed and static satellite and terrestrial line of sight components to a network that provides BLOS connectivity, which is multi-tiered in depth and in capability. Therefore a concerted effort is required to mature existing platforms and concepts mentioned earlier, to in fact provide an aerial networking tier capability to the Marine Corps. The aerial tier will extend the terrestrial and satellite network into the region between the ground and space domains. The addition of an aerial tier to the existing terrestrial and space tiers of the network will enable connectivity regardless of movement or environment. Ultimately a responsive and maneuverable aerial tier will enable the network to support a rapidly deployable and highly mobile Marine force.

The Air Force has been shaping and maturing these aerial tier concepts by focusing on increasing joint forces communications network capacity at all levels and across the range of military operations (ROMO).[15] The Aerial Layer Network (ALN) roadmap created by the Air Force attempts to set the framework for ALN's to support disconnected, intermittent, low-bandwidth users by extending the range and gateways between tactical data links (TDL).[16] Additionally aerial layer networks are envisioned to augment the Global Information Grid (GIG) access, which is currently provided by the surface and space layers.[17] Lastly it is imperative to understand that the concepts and capacities mentioned above require extensive resources, namely appropriated funding lines to support their efforts. As the DoD prepares for impending defense spending cuts, it becomes that much more important to synchronize acquisition efforts and envisioned concepts with other joint partners. If not done properly, the services risk increasing capability gaps and thus reducing the warfighting edge.[iii] Ultimately this fiscally constrained environment will force this interaction among services and will facilitate novel approaches to future national security threats. A shining example of this is the work being accomplished currently on the aerial tier by the Air Force and Army. Services have come to the realization that there are a limited number of satellites in orbit due to the high cost associated with this resource.

[iii] Dan Ward, *Tactical Radios: Military Procurement Gone Awry*, National Defense Industrial Association, July 2012. The Army cancelled the Joint Tactical Radio System (JTRS) Ground Mobile Radio for technical challenges and the realization that products resulting form the JTRS GMR program will not meet service requirements. This cancellation came despite the Army spending $6 billion over 15 years and failing to produce much in the way of actual radios. Additionally the Army spent $11 billion for radios on emerging requirements for both Iraq and Afghanistan. This type of systemic failure is predicated by a universal system that is based on contradictory requirements instead of focused systems grounded on a technically and operationally coherent vision. This example portrays the importance of synchronizing acquisition efforts in the future, one in which will require frugality amongst the services to ensure support to the warfighter.

The approximate cost of each geosynchronous satellite is $200 million, which makes it cost prohibitive in assigning dedicated SATCOM channels to each unit executing military commitments throughout the world.[18] Dilemmas such as this will only serve to increase collaboration and ingenuity for the future.

The intent for this background was to portray the importance of the aerial tier in extending network capabilities and overall capacity to the tactical edge. It also attempted to provide a general appreciation and context for future-operating environments the Marine Corps may face and those capabilities its operators will require in regards to redundant, available, and reliable communications networks. Additionally, systems that provide some utility in regards to BLOS and On-the-Move (OTM) communications were presented for reference. While these systems reveal significant technological advancements in communications capabilities at higher echelons of command. The goal however, should focus on making these technological advances available to all elements of the MAGTF. The following section will discuss current C2 gaps and the overreliance of certain systems to overcome hindered network capabilities on the battlefield.

Current C2 Gaps

Marines continue to conduct very diverse mission sets, from humanitarian disaster relief efforts (HA/DR), to theatre support cooperation (TSC) partnering around the world, to ultimately strategic actions in defense of the nation's interests. Additionally while not dominating in any one domain, Marines conduct operations throughout the air, land, and sea. This requires the Marine Corps to equip its forces with highly redundant and highly mobile communications devices. These maneuver elements require extended range connectivity, higher throughput, and support to large numbers of dispersed tactical users. As discussed in the background, ideally an interlocking network, similar in fashion to a civilian cellular network, would provide maneuver element requirements. The Marine Corps however remains an expeditionary force, and primarily finds itself operating in austere environments. Environments such as these, by very nature, lack available resources such as infrastructure to support communications links at the tactical edge. This is not a phenomenon only synonymous with Marine Corps operations. The Joint Operational Access Concept describes:

> That some operations to gain access will occur in austere environments lacking the Infrastructure typical of modern societies. In the aerial-denial case, many conflicts will arise in failed or failing states where infrastructure is lacking. In such cases an advancing force will have no option other than to operate under austere conditions.[19]

To address these challenges, the military developed the Mobile Network Infrastructure, and the Combat Net Radio (CNR) program as a subsystem. The CNR program placed tactical radios on vehicles and man-packs to serve as nodes in the C2 network. By placing systems on vehicle platforms, mobility and limited range extension was achieved. Range extension was provided by the use of high power amplifiers installed in vehicles. The radio systems in the CNR program consisted of High Frequency (HF), Very High Frequency (VHF), Ultra High Frequency (UHF), and UHF SATCOM. The variety in frequency ranges provided military planners options, when tackling communications requirements for a variety of missions. These systems were predominately designed as half duplex, capable of providing only voice communications. Improvements to these systems over the years did enable limited data to be transported mainly via point-to-point links. Additionally, this limited data capability was often times leveraged through the SATCOM medium, in order to overcome terrain or obstacles. While extremely capable at their functions, CNR systems are inherently restricted by their LOS requirements. Thus, ground relays must be adhered to, in order for highly dispersed forces to communicate with each other. Additionally these systems provide very little data capability to their users and lack any ability for increased capacity requirements. While these systems are still critical to mission success for the Marine Corps, serious gaps in C2 coverage will be the reality for maneuver elements at the tactical edge.

With the advent of data networking, specifically Internet Protocol (IP) architectures, the military began to develop tactical network capable radio systems. These systems allowed for automation and increased data capabilities across the battlefield exponentially. Additionally, unique waveforms were generated to negate some of the aspects of harsh environments where units were operating. These waveforms relied on robust algorithms that enabled adhoc networking, ultimately leveraging existing radio frequencies such as HF, VHF, and UHF. This enabled ground forces to establish tactical wide area networks (WAN) and permitted entry to the GIG. Ultimately the move to both IP and common standard protocols supported the joint force in linking dissimilar devices together to provide interoperability through gateway and routing capabilities. Examples of such systems today include the Advanced Field Artillery Tactical Data System (AFATDS), and the AN/PRC-117G. Both systems are unique in their overall mission sets, but both provide tactical users access to the WAN and GIG. Self-forming and self-healing attributes were additional off shoots to these networkable radios, ultimately allowing for much more redundancy and scalability in the overall network presence. Even though however these advancements have somewhat extended the network to disadvantage users, they still rely on CNR type systems for their transmission requirements. This limits their overall effectives in operating over large distances since they are limited to LOS parameters. To mitigate these constraints, communication retransmission sites are required to be emplaced throughout the battlespace to ensure links are established between devices. This is similar to the requirement discussed earlier on interlocking network requirements. Therefore these systems will always require an advantaged node, such as an aerial relay capability in order to fully garner their capabilities.

The overarching issue with both CNR systems and the tactical data network radios is their heavy reliance on both terrestrial communications and space-based communications for extension into the network. Because of this, the notion of communications support to tactical maneuver forces, which are highly dispersed and mobile, is truly unachievable in its current state. What is achievable at best is an increased communications capability at-the-halt (ATH) only. This however requires advance planning, long lead-times for link establishment, and extensive training. Furthermore situational awareness (SA) and C2 will be unavailable to units while on the move, which negates overall combat effectiveness. The *MAGT C2 Roadmap* recognizes this gap and provides an analysis of validated Net-Enabled C2 capability gaps which include:

Capability	**Current Gap**
Situational Awareness (SA)	*Inability to provide SA and friendly positional location across the MAGTF to the tactical level*
Common Operating Picture (COP)	*Info flow to the decision-maker used to provide SA is incomplete and not timely*
System Throughput Capacity	*Insufficient bandwidth to provide for multiple circuits and networks to support operational requirements for maneuver units on-the-move*
Network Capacity	*Insufficient ability to provide sufficient information transport capacity (Mbps) ATH. No capacity to provide additional capacity for on-the-move*
Collaborative Planning	*Limited ability to conduct planning in a collaborative manner to the squad level*
En Route Planning and Rehearsal	*Limited capacity to plan, model, and rehearse operations while on-the-move, from any platform*

Table 2. USMC Net-Enabled C2 Capability Gaps, FY13 MAGTF C2 Roadmap

With the major limitations listed above, the preponderance of effort to mitigate such gaps has rested solely on increased SATCOM use throughout the Marine Corps, DoD joint forces, and other government entities. This however will only take the service so far and will ultimately increase, not decrease the digital divide at the tactical edge.

A recent example of this heavy reliance on SATCOM and inability to access the network by a tactical maneuver element took place during Rim of The Pacific (RIMPAC) Exercise 2012. During the event an infantry battalion conducted amphibious operations as part of unit training and in support of the larger RIMPAC objectives. Throughout the exercise the battalion was unable to access network capabilities for data and phone connectivity disrupting coordination and overall C2 capabilities.[iv] While the battalion was equipped with both CNR and tactical data radio systems, ultimately they were unable to access the network when conducting amphibious operations. This led to the battalion requiring infrastructure support once ashore to leverage network capabilities. This practice of either leveraging infrastructure or relying strictly on SATCOM assets is not isolated to RIMPAC. The question then that should be raised, is what will the Marine Corps employ to mitigate risks, when satellite capacity is inundated, no infrastructure exists to leverage or enemy capabilities render the systems unusable?

[iv] U.S. Marine Corps Center for Lessons Learned, *Maritime Exercise RIM OF THE PACIFIC*, December 2012, 28. The BLT relied heavily on High Power Waveform (HPW) via the PRC-117 to transmit over SATCOM. But due to the Support Wide Area Network (SWAN) being inoperable the BLT resorted to a reliance on the garrison network for data and phone connectivity during operations ashore impacting their overall C2 coordination efforts.

Today exists a glaring vulnerability for the Marine Corps in regards to tactical communications. This vulnerability is equated to entrenched satellite reliance. SATCOM is so relied upon that without its presence is unimaginable in today's force. Is SATCOM truly the answer to meeting the needs of forces at the tactical edge and do we rely on SATCOM entirely too much? One interesting aspect to SATCOM is the engrained over reliance on this one spectrum. In traditional warfighting systems, the concentration of so much capability onto a single platform is traditionally met with disaster.[20] Because domination of space belonged to the U.S. for decades, the need to rebalance assets and capabilities was relegated as a mute point. Today however, the domination in the space domain is waning. Space technological strength is no longer an American monopoly; multiple nations now boast a fully developed space industrial base. By 2011, over 50 countries had at least one satellite in orbit and can continue to buy additional capabilities from an increasing number of companies that provide space technologies to the world.[21] Even more sobering is the ability for state and non-state groups to jam or render satellites unusable. This technology is fairly simple and can easily be assembled by either individuals or nations for a fairly modest investment.[22] From a strategic standpoint much risk is now assumed in placing such a heavy reliance on space systems. How then do space systems affect both operational and tactical aspects of C2?

Operationally, space-based communications assets do extend BLOS capabilities, but they are limited in numbers; costly and difficult to relocate; not responsive to commanders in a timely fashion; and limited by available bandwidth.[23] Additionally current and projected numbers of military satellites are too few to sustain the future force. Commercial satellites have supplemented this shortfall; however they are extremely expensive and are rarely under military control. It is estimated that future network capacity will only meet 44 percent of warfighter requirements.[24] This does not bode well for the tactical edge user, since competition for scarce resources will likely result in increased C2 gaps and render concepts such as EMO unachievable in the scope desired. Lastly the quality of service provided via SATCOM does have drawbacks. Satellites create latency, based on the time it takes for a transmission to go from the ground to space to ground. This latency has a negative effect on data transmissions and especially services such as video, imagery, and Voice over Internet Protocol (VOIP).[v] Additionally these systems are only now affording units the opportunity for mobility in a limited scale. Now understanding the limitations and risks associated with satellite communications, then how then do you mitigate the C2 gaps as discussed earlier? The only plausible solution is to create and mature a robust aerial tier network as an augment to existing terrestrial and space systems.

Current UAS systems are a step in the right direction, however they too contain gaps in providing the proposed network expansion required on today's battlefield. Many current UAS systems were designed and fielded for specific niche applications, namely intelligence. The systems lack sufficient capability to enable a robust network to fully support information and knowledge connectivity with required capacity throughout the extended operational environment. Furthermore, they lack standardization and interoperability required for sustained UAS resource allocations.[25] This is yet another C2 gap that must be mitigated in the future in order to leverage these assets for increased network expansion.

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[v] The Brookings Institute, *The Evolution of Joint Special Operations Command and the Pursuit of Al Qaeda in Iraq: A Conversation with General Stanley A. McChrystal,* Washington D.C., 28 January 2013, 11. Elements of 15 operators were executing missions in 15 locations throughout Iraq. These elements were able to ascertain vital information about the battlespace, but problems arose when the elements were unable to send this information to higher headquarters or each other. Their physical pipe or bandwidth back to higher headquarters was limited. They could send email and make phone calls, but imagery and large documents were unable to be passed. The consequence was having two elements basically spinning around on their own without really being joined into the fight. This example portrays the inefficiencies of SATCOM when leveraged for data services.

All the services understand the importance of mitigating these C2 gaps and are beginning to address such gaps through select programs. The next section will provide background on current DoD initiatives that are attempting to codify this aerial tier capability.

DoD Initiatives

With the advent of networkable radio systems and more specifically software-defined radio systems (SDR)[vi], the notion of providing tactical edge warfighting elements increased network coverage and data capabilities was becoming reality. These systems enabled significant amounts of signal processing to be accomplished by a general purpose processor rather then inflexible special hardware solutions. Thus, this shift produced radio systems that were able to receive and transmit signals in widely different radio protocols or waveforms depending on the specific software that was leveraged. These innovations were paramount in encouraging, embracing, and accepting new ideas that involved much risk, but were vital in producing mitigating aspects to today's C2 challenges.[26] Most importantly these innovations, drastically increased warfighters C2 capabilities and have contributed to the creation of a fresh tactical C2 lexicon for the services throughout the DoD. This lexicon shift is the first step and will act as the basis for the continuation of programs and initiatives throughout the DoD.

In response to the Joint Aerial Layer Network (JALN) initial capabilities document (ICD), approved in August 2009, the Air Force has become the lead service for maturing both technologies and concepts for this initiative. The desired effects of the JALN program is to support warfighter net-centric, C2, and battlespace awareness information requirements by connecting and/or reconnecting warfighters executing specific missions and tasks in a challenging or degraded communications environment.[27] Furthermore the envisioned JALN high capacity backbone and range extension functions will provide an alternative to space-based connectivity when this access is denied by enemy actions and/or physical access limitations. Ultimately the desired effect of JALN is to reduce joint forces reliance on relatively limited fixed/static satellite and surface LOS communications components.[28] The JALN ICD also identified four current gaps: connectivity, capacity,

[vi] Gerald Youngblood, *A Software-Defined Radio for the Masses: Part 1*, QEX American Radio Relay League, Newington CT, July-August 2002. 1. A software-defined radio is characterized by its flexibility: Simply modifying or replacing software programs can completely change its functionality. This allows easy upgrade to new modes and improved performance without the need to replace hardware. There is a distinct difference between a radio that internally uses software for some of its functions and a radio that can be completely redefined in the field through modifications of software.

information sharing, and network management. Additionally the Air Domain Operational View (OV)-1 was created in order to graphically display key battlefield parameters such as anti-access, contested, and permissive battlespace regions.[29] Figure 3 displays the JALN ICD Air Domain OV-1.

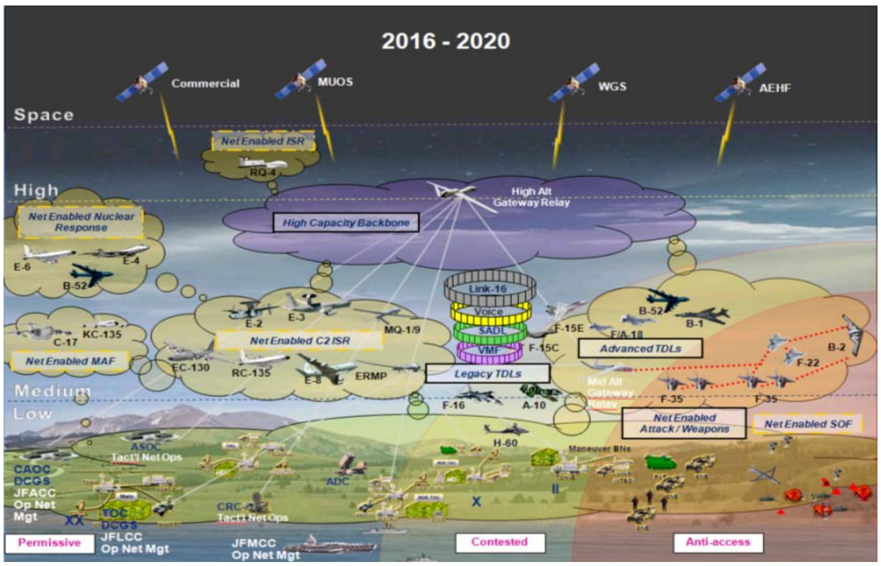

Figure 3. JALN ICD, Air Domain OV-1

To support JALN desired effects, the innovations mentioned earlier in regards to SDR technologies will help bring these concepts closer to reality.

Subsequent to the JALN ICD approval, the Air Force (AF) has drafted a myriad of documents to better codify the AF's vision and further refine gaps and establish aerial layer networking (ALN) baselines. Some of these documents include: AF Vision for ALN in 2024, AF Flight Plan for ALN, and AF Aerial Layer Networking Enabling Concept. Ultimately, the AF ALN is not a network in itself, but rather a framework which guides many networking capabilities the AF will employ in the aerial layer to help develop the JALN as envisioned.[30] It is also important to understand, as with any emerging concepts, that time horizons will be significant based on availability and maturity of advanced technologies. Thus, the AF will field airborne network capabilities incrementally over a period of several years with full capability reached in 2024. To ensure these timelines are met, the AF has organized baseline gaps for the ALN program. Table 3 identifies current baseline capabilities in line with the overarching AF ALN Vision.

Currently as identified by AFL baseline capability gaps, the AF has only limited capability and or connectivity in extending networks to units operating in highly contested regions. Additionally the AF only has limited capability in augmenting space and surface networks. This specific gap will force other services to look for organic means in augmenting the space and surface networks that already lack the ability to support highly mobile forces on the tactical edge as discussed earlier. Additionally as more services become interdependent on capabilities such as the ALN program, competition for resources will become a reality and also force services to look inward for capabilities. This will become apparent as ALN concepts mature, ultimately forcing the AF to dedicate aircraft with committed networking assets. How these assets will be managed and proportioned to the joint force remains to be seen.

AF ALN VISION	AF ALN BASELINE
1. Extend and augment space and surface networks	The AF **has limited** capability
2a. Share information to enable new operational concepts between platforms and units operating within the Highly Contested region	The AF **has limited** connectivity
2b. Share information to enable new operational concepts between platforms and units operating in the Highly Contested region with those in the Permissive and Contested regions	The AF **has limited** connectivity
2c. Share information to enable new operational concepts between platforms conducting air-to-air operations in the Permissive and Contested regions	The AF has the ability to exchange information for air-to-air operations but future operational concepts create **connectivity and capacity** issues
2d. Share information to enable new operational concepts between platforms and units conducting air-to-ground operations in the Permissive and Contested regions	The AF has the ability to exchange information for air-to-ground operations but future operational concepts create **connectivity and capacity** issues
3. Plan and execute aerial layer networks	The AF **has limited** network management capability

Table 3. AF ALN Vision versus AF ALN Baseline

One aspect of the ALN program that portrays promise in extending network services to the tactical edge is the Battlefield Airborne Communications Node (BACN). The BACN is a dedicated airborne communications relay and gateway that leverages AF platforms such as the EQ-4B and E-11A. This system allows interconnectedness between different tactical data links (TDL) communicating on different waveforms and enables voice relay and limited data capabilities to ground forces. Additionally it provides ground units access to the GIG via onboard SATCOM links.[31] What makes this system so relevant in today's battlespace is the AF's dedication of assets to a communications relay system in an airborne platform. This system will continue to mature by adding additional waveforms and data links for increased interoperability. Ultimately, the system is envisioned to provide the following capabilities: TDL gateway and range extension, voice relay, bridging, and range extension, and extension of GIG access and services to tactical edge users.[32] Figure 4 depicts E-11A and EQ-4B platforms.

Figure 4. BACN Platforms E-11A and EQ-4B

After reviewing the AF concepts and capabilities for ALN, it is important to review and understand what other services are attempting to accomplish in attaining an aerial tier capability. The U.S. Navy sponsored a study by the RAND Corporation to evaluate the Navy's ongoing and proposed UAS programs and to describe the most promising applications of UASs to operational tasks.[33] One application of note was the recommendation for the Navy to mature airborne communication relays through UAS mediums in order mitigate kinetic and noise jamming threats to satellite communication uplinks.[34] To meet this proposed application for communication relay capabilities through UAS platforms, the Navy has procured systems and is continuing to test and mature technologies. These systems consists MQ-4C Triton and the MQ-8B Fire Scout. The primary purpose of these systems is to provide maritime patrol and reconnaissance force capabilities, ultimately aligning with the Navy's intelligence, reconnaissance, and surveillance (ISR) recapitalization strategy. While extremely capable systems, the Navy is only employing basic communication packages consisting of VHF and UHF BLOS range extension parameters. Perhaps in the future more advanced communication packages will be introduced to these platforms and ultimately leverage their high altitude and long endurance capacities.

The Army is arguably advancing the aerial tier more advantageously then any other service currently. This is attributable to the Army's Warfighter Information Network-Tactical (WIN-T) program, which is being implemented in three increments, the first of which is currently fielded. The WIN-T program focuses on providing seamless, assured, mobile communications to corps elements down to the company level.[35] Both the first and second increments provide increased data capabilities to forces while at-the-halt with a heavy reliance on satellite technologies to negate LOS issues throughout the battlespace. Increment three is focused on introducing the aerial tier capability to the Army and joint forces in order to provide the commander/user a mobile infrastructure that passes relevant information effectively and efficiently for combined arms capabilities in all required terrain and environmental conditions.[36] Initial operational capability of increment three is currently estimated for FY20. In the interim, the Army is also advancing its airborne radio capabilities.

By developing the Small Airborne Networking Radio (SANR) and the Small Airborne Link 16 terminal (SALT), the Army is attempting to bridge the gap in connecting the tactical edge before full implementation of WIN-T increment three. Both the SANR and SALT are being developed as communication suites that will reside on the Apache, Chinook, Gray Eagle, Black Hawk, and Kiowa Warrior aircraft.[37] Additionally both these systems are employing SDR capabilities and advanced waveforms as discussed earlier. The initiatives and programs reviewed in this document are in no way an exhaustive list of technologies being developed, in regards to tactical communications across the DoD. They are however, the most relevant to fulfilling aerial tier requirements for the future. Before moving forward to a path ahead requirements for the Marine Corps advancing aerial tier capabilities, it is imperative to understand the Marine Corps current initiative in addressing network extension to units operating OTM and over-the-horizon (OTH).

The Marine Corps is currently developing the Network On-the-Move (NOTM) based on an Urgent Universal Need Statements (U-UNS) submitted during both OIF and OEF requiring OTM, BLOS, and OTH communications capabilities. NOTM is a communications system that extends network connectivity from a fixed location to units operating OTM and OTH. It will be fielded to all levels of the MAGTF and is intended to deliver the capability of a self-forming, self-healing, ad-hoc mobile network.[38] NOTM enables mobile forces to collaborate and access C2, ISR, applications, e-mail, chat, collaboration tools for real-time exchange of voice, video, and data services to users throughout the MAGTF while OTM or ATH.[39] Additionally NOTM is envisioned to provide a Point of Presence (POP) or primary hub for both mounted and dismounted users through the use of SATCOM and terrestrial mediums. This POP would then provide services to staff vehicle kits (SVK's) and staff kits (SK) primarily through LOS wireless devices. Ultimately this program provides much in the advancement of MAGTF expeditionary communications, but falls short in one critical area.

The program unfortunately does not address an aerial tier increment or a like capability for the future. Instead, it is solely reliant on satellite and terrestrial systems to meet its full capabilities. Thus, this will place Marine Corps concepts such as Mission Command, EMO, and Distributed Operations are at risk in the future. To thwart this risk, the Marine Corps will require true innovation and adaptability in providing mobile key leaders and tactical edge elements the most reliable and available network, despite the enemy threat, terrain or environment. The following section of this document will discuss and propose steps the Marine Corps must take in advancing an aerial layer network capability in support of MAGTF operations.

Proposed Path Ahead for the Marine Corps

As the Marine Corps continues to move into the networked future, both the scope and complexities of operations will be characterized by asymmetrical warfare principles. This will in turn, force both adaptation and innovation from Marine Corps system developers, acquisition personnel, and tactical units, to ultimately experiment with and field C2 systems that enable network integration to all elements of the MAGTF. This is paramount, in ensuring connectivity and capacity are accessible at critical points in operations. Therefore in the near term, the Marine Corps must make some strategic decisions regarding the synchronization of all future C2 efforts. In doing so, the Marine Corps can mitigate risks in fully networking highly mobile tactical elements, that are unhindered by terrain or dispersion connectivity issues.

Under the current fielding programs however, the preponderance of current and future ground networks will be deployed years ahead of a mature aerial layer networking capacity. This reality however, does not alleviate the Marine Corps responsibility in incorporating, testing, and implementing aerial layer network technologies and systems on existing platforms and programs. Therefore, if the Marine Corps hopes to leverage a fully integrated network to support future combat operations, three steps must be taken in earnest. These steps include: incorporating an aerial tier capability into the existing NOTM program, inclusion of aerial tier concepts into Marine Corps existing and future concepts, and finally leveraging existing aerial layer network programs throughout the DoD and conducting comprehensive experimentation with novel technologies and refined aerial tier concepts.

Incorporation of Aerial Tier Capabilities into NOTM

The NOTM program as envisioned by the Marine Corps significantly increases network capacity to units operating OTM and OTH through the extension of network connectivity from fixed locations. Additionally the NOTM system claims to support Enhanced MAGTF Operations (EMO)[vii], by enabling C2 capability down to the squad level.[40] Table 4 provides an illustrative matrix created to assist with providing specific detail to the requirements for the development of EMO. The preponderance of the crux items displayed, are centered on complex environments, dispersion, mobility, and mutual support.

Function	Essence	Crux	Enhancements
C2	Decentralized execution synergized by commander's intent	Shared situational awareness (up) and dissemination of commander's intent (down) accross domains in remote and complex environments.	Proliferate agile decision-makers, promote an environment of trust and initiative, develop decision tools that enable sharing SA and intent
Log	Transportability & Mobility	As units operate in more dispersed, less linner formations, the physical limmitations of logistics remain constant.	More self - supportive units; lighter more efficient , leveraging technology alternate fuel sources, water purification and unmanned systems
Fires	Integrated & responsive	Maintain all-weather combined arms synergy and Force Protection while both fire and maneuver forces are dispersed.	Non-traditional relationships, automated observer to FSCC/ FDC tools, lighter more deployable fire systems, JSF
Maneuver	Gain/Maintain relative advantage to concentrate and disperse	Mobility over varied terrain and domains	Mission vehicle mobility sets to optimize for terrain
Intel	Ability to process information into knowledge at the point of action	Real time collection, fusion & dissemination of intell elements and intuitive products	Intel cells at lower level/ improve intel networks Tailored, automated and balanced Information pull (passive) and selective push.
Force Protection	Protection over all domains, inclusive and proactive.	Absence of mutual support	Enhanced networks, comms, fires, mobility
Information	Induce self-disadvantagious action by the enemy	Timely pattern recognition	Infromation planning and execution throughout all levels of command.

Table 4. EMO Capabilities Matrix

[vii] U.S. Marine Corps, Deputy Commandant for Combat Development and Integration, *Marine Corps Operating Concepts Third Edition*, June 2010. 29-32. The EMO concept pushes all elements of the MAGTF to become lighter, more adaptable, more resourceful and faster in relation to the enemy. EMO recognizes the need for decentralized action to solve complex problems, and adapt to ambiguous situations at a tempo that outpaces that of our adversaries. Through EMO we have the ability to extend the battlespace and likewise to improve our capability to concentrate when required generating increased levels of responsiveness, precision, and versatility.

Thus, the NOTM program is attempting to provide enhancements and ultimately decrease the digital divide at the tactical level by incrementally fielding networking capabilities well below the MEF and Division level. To accomplish this, the NOTM program relies entirely on terrestrial and satellite mediums for network expansion.[41] This sole reliance however, is a mistake and will provide more of the same to highly dispersed and mobile elements across the battlespace. That is, an insufficient capacity for extending the network in complex terrain and a continued perpetuation of service competition for scarce satellite resources.

The Marine Corps ultimately must expand the scope of the NOTM program by incorporating an increment three proposal, similar in fashion to the Army WIN-T program. This would require a focus on aerial tier capabilities currently and into the future. Incorporation of an increment three into the NOTM program would also require an expansion of both key system attributes (KSA) and key performance parameters (KPP) to the system as a whole. Therefore programmatics such as hardware, platforms (vehicle and airborne), software, power, training, costs, integration, interoperability, and network management parameters must be formulated and flushed out. This in turn would significantly expand the NOTM's future capabilities and align the program more advantageously as aerial network technologies mature. The Army has accomplished much of this work and exhaustive studies of the WIN-T program specifically increment three, will facilitate a catalyst in accomplishing this required aerial tier incorporation into NOTM.

Programmatically the NOTM initiative does allude to future increments, through the advancements of both technology and lessons learned.[42] Additionally, the NOTM's capabilities development document (CDD) states that future increments of NOTM will be interoperable with existing and planned aerial communications platforms family of systems (FoS).[43] These statements do provide foresight or at least the recognition of future aerial tier incorporation into NOTM. However, they do not provide the required path ahead on the subject and thus potentially leaves the Marine Corps behind the other services in the development of this capability. Most troubling however, is the proposed reduction in budgets across the DoD. This will inevitably impact the ability for the Marine Corps to incorporate further increments if not identified in the near term, with realistic and justifiable parameters for an aerial tier. Therefore the Marine Corps is obligated to advance an additional increment for the NOTM similar to the WIN-T increment three initiative. Some would argue however, that fiscal constraints render this incorporation or addition of an increment unrealistic, since the Army and Air Force are appropriating significant amount of resources to this initiative. Such a stance overlooks one key aspect. The Marine Corps plans and conducts unique operations that many times require exclusive technological capabilities. By solely relying on the Army and Air Force to develop aerial layer network technologies, the Marine Corps assumes much risk for the future, primarily when advancing concepts such as EMO, Mission Command, and Distributed Operations in regards to C2 requirements. Ultimately the Marine Corps understands the risks associated with the above concept, specifically as they align with C2 challenges. These were expressed in the *MAGTF C2 Roadmap* document mentioned earlier. Therefore to mitigate such risks in the future and to close the digital divide, a third increment to the NOTM program, incorporating an aerial tier is a necessity.

Inclusion of Aerial Tier Concepts

The second step the Marine Corps must take in advancing an aerial tier capability is to infuse aerial relay networking ideals, whether conceptual or practical based into Marine Corps operating concepts. This infusion will ultimately facilitate a more comprehensive and realistic stance in pursuing an additional aerial tier increment, into the NOTM program. The foundation for this inclusion already exists. *The Marine Corps Operating Concepts* puts forth six operating concepts that are envisioned to enhance the Marine Corps contribution in preventing conflict, protecting national interests, and assuring overseas access.[44] These six concepts include: Mission Command, EMO, Engagement, Crisis Response, Power Projection, and Countering Irregular Threats.[45] The underlying foundation of each concept is to promote flexibility and effectiveness across the range of military operations and to address challenges in permissive, uncertain, or hostile environments.[46] This is plausible and seems to coincide with the JALN ICD battlespace regions assessment of anti-access, contested, and permissive environments mentioned earlier. One key difference however, is the lack of vision for an aerial tier network in the current operating concepts. Increases in UAS capabilities, specifically intelligence gathering/dissemination and logistical resupply are afforded a vision, to better align research and development, acquisitions, and doctrine development for future systems.[47] Conversely, the only dialogue for improved and expanded communications in the current operating concepts is a reiteration to the importance of OTH and OTM information flow.[48] While an extremely important requirement and one in which the NOTM program is looking to achieve, the current operating concepts are incomplete. Ultimately concepts are formulated to guide current and future development and experimentation. Most importantly they drive innovation through capability identification. This then lends credence to the importance of infusing an aerial tier capability to existing concepts.

A successful example of a concept maturing to an operational capability is the Cargo Resupply Unmanned Aerial System (CRUAS) initiative. An early attempt to solve logistical limitations for the Distributed Operations Concept quickly materialized into a realization for increased logistics capabilities throughout Afghanistan. The Marine Corps Warfighting

Laboratory (MCWL) in conjunction with the Office of Naval Research (ONR) solicited industry in 2009, with a concept of autonomously delivering sustainment supplies to forward operating elements throughout remote locations.[49] The program centered around two key aspects that coincided. To deliver much needed supplies to the warfighter and to negate exposure of warfighters to roadside improvised explosive devices (IEDs) and hostile fire usually accompanying convoy operations. Through integration efforts, the system deployed to Afghanistan in 2011 and 2012 as a test prototype. Remarkably in just two years a concept was matured and made available to the operating forces. This example illustrates the importance of innovation through sound supportable concepts. It also displays the increased capacity and operating parameters of UAS platforms for the future. Ideally a successful aerial tier will follow, but first it will require recognition from the Marine Corps as a suitable means to augment existing terrestrial and satellite communications capabilities, increasing the overall capacity for tactical network connectivity. For this reality will only deliver the true innovation and adaptability required for the future.

Leveraging Existing Systems and Experimentation

The third step the Marine Corps must take in making the aerial tier a reality is to leverage existing systems throughout the DoD and to drive experimentation with such systems. Ultimately, other services have matured both aerial tier concepts and technologies far in advance of the Marine Corps. This necessitates initial utilization of existing systems that can be experimented with and adapted for perhaps immediate use. Systems such as the Air Forces

BACN, the Army's SANR, and the Navy's MQ-4C Triton show promise and should be viewed as an opportunity for the Marine Corps to not only mitigate its own C2 gaps, but also provide economies through developmental partnership. This partnership would also ensure a unified coalition in maturing overall joint concepts and thus fulfilling the envisioned Joint Aerial Layer Network. Understanding the importance of a collective effort, how then must the Marine Corps pursue this desired capability?

First and foremost, the Marine Corps must identify a dedicated platform that can be leveraged as a proof of concept or a demonstration platform. In order to reduce the impact on operational UAS programs, it is recommended that the Marine Corps select a fixed wing or rotary wing asset for this aerial tier concept platform. Subsequent to selection, the Marine Corps should integrate existing organic technologies such as SDR waveforms already incorporated into NOTM for testing. Ultimately this testing should incorporate realistic operational scenarios under a concept based experimentation construct. This experimentation would be ideal for annual exercises such as Bold Alligator, RIMPAC, and Weapons Tactics Instructor (WTI) courses. These exercises provide an excellent venue for experimentation since they usually incorporate the entire MAGTF into exercise scenarios and also afford the availability of amphibious shipping. This is especially crucial, since the Marine Corps has articulated its aspirations and requirement to focus the force for amphibious operations in the future. Additionally the Marine Corps requires the integration of existing technologies such as BACN and WIN-T waveforms in order ensure interoperability amongst the services. Ultimately lessons learned from the use and testing of this system will refine aerial tier concepts for the Marine Corps and drive emerging requirements for future increments of the NOTM program. Therefore through concept based experimentation, the Marine Corps will not only advance its own C2 capabilities, but also expand and help in maturing existing Army, Air Force, and Navy aerial tier technologies. Additionally this experimentation will ultimately lead to a better understanding of costs, force structure requirements, ancillary support requirements, and training to make the aerial tier a reality for the Marine Corps.

Conclusion

To remain flexible and agile in anticipated complex environments of the future, the Marine Corps must remain innovative in the development of new concepts and technologies. Most importantly, a focus on expanding C2 and situational awareness to small unit leaders to support decentralized decision-making is paramount. Thus far acquisition programs, rapid equipment fielding's through the Urgent Needs Statement (UNS) process, commercial off-the-shelf (COTS) solutions, and adhoc measures to realize this requirement have mitigated some risks. However to truly close the digital divide gap and posture the Marine Corps as the crisis response force for the 21st century, a paradigm shifts in thinking is required. This will ultimately require the incorporation of an aerial tier concept and capability for the Marine Corps. This aerial tier will effectively augment existing terrestrial and satellite systems and ultimately further enhance concepts such as Mission Command, EMO, and Distributed Operations in the realm of communications. Lastly, the emphasis on developing an aerial tier capability will align the Marine Corps with DoD requirements for the development of the JALN program. Therefore the aerial tier may not be a program the Marine Corps can avoid or disregard, but actually a necessity for the foreseeable future.

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[3] Army Aerial Layer Way Ahead Position Paper pg. 5

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[5] Ibid., 20.

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